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## Information technology for sustainable development

*a problem based and project oriented approach*

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# **Paper 21. Information technology for sustainable development**

## **- a problem based and project oriented approach**

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### **Abstract**

In this paper we present different strategies to integrate concerns about sustainability into Information and Communication Technology (ITC) projects by use of problem based learning (PBL) methodology. In alignment with PBL we introduce two different models for problem analysis where students move from a broader theme to a problem formulation designed to fit the time, discipline and theme of study. In the prospect of Education for Sustainable development (ESD) the students are to move from the conceptually complex field of sustainable development (SD) to a specific formulation of a problem that initiate design, implementation and test of ICT for SD. On the empirical level we draw from experiments in autumn 2009 and spring 2013 within the field of Media technology. Observations, text analysis of students' work as well as reflections from staff has been relied on in order to analyse the practical implications of the different approaches to integrate sustainability. We conclude that students indeed chose diverse strategies to integrate sustainability into their projects and those diverse strategies are indeed needed to obtain student engagement. Furthermore, the introduction of an open-ended thematic frame, like sustainability, encouraged students to broaden their perspective on stressing economic, environmental as well as social concerns. However, the experiments also showed that interlinking engineering subjects with sustainability is a rather time-consuming task – and some of the students were struggling with these open-ended themes at the same time as they were struggling with the rather open-ended perspectives on how to manage and structure a problem based and project organised project.

### **1. Introduction**

As sustainable development is seen as one of the grand challenges of our time, attention has increased towards integrating sustainability in educational activities at all levels (Gough & Scott, 2007; Sterling, 2004). If we want citizens as well as professionals to act in a sustainable way, we have to provide them with the competence to in fact do so. As an example, if we want technological innovations to be assets and not threats to SD, we have to educate engineers to take sustainability into consideration in the making of technology or even to make solutions that foster SD. Also because that the users of a specific technology might not necessary prompt for sustainability – it is as Hardin (1968) stressed the tragedy of the commons.

For engineering and science education in specific, the challenge differs depending on whether material or immaterial products are targeted in the learning process. For material products, environmental and social impacts are connected to the full product lifecycle including resource extraction, processing, use and disposal. Many of the impacts are due to decisions made during the design process (Remmen & Münster, 2003). For immaterial products such as services, information and software applications,

sustainable developments instead might be found in changed individual attitudes, behaviours and practices into more sustainable directions.

In this paper we will focus on how sustainability can be integrated into science and engineering education aiming at immaterial products in the fields of ICT. The challenge is then to build sustainable patterns of action in students. However, there are many premises that have to be settled before action is taken. First of all, there have to be awareness of sustainable alternatives including access to relevant information; secondly, there have to be a will to take the sustainable alternative, and finally the conditions in the surrounding environment have to be handled (being for example, infrastructural, economic or other). In an ICT perspective, several examples have shown that human computer interaction can be an asset in:

- creating awareness about sustainability and foster incentives to act; see for example <http://climatekids.nasa.gov/menu/play/> or <http://www.epa.gov/mygreenapps/>
- and provide feedback on behavioural patterns for self-evaluation; see for example: <http://www.mobilenewscwp.co.uk/2012/07/27/ee-uses-cloudapps-software-to-measure-carbon-footprint/>

These technologies call for interdisciplinary collaboration and understanding, and the last implies that the ICT expert should be able to understand as much about sustainability that they can relate to the concept and use their creativity to unfold new ways of exposing, fostering and reflecting of sustainability in the use of technology. Even better, engineers and scientist should internalise sustainability to an extent that every technological innovation to which they contribute is questioned in that respect. From an engineering education point of view the question is then, how we prepare our students to take upon them the responsibility of providing solutions designed for sustainability in specific and develop a more comprehensive perspective of product quality in general. Educating into this perspective claims undoubtedly to a student centred, problem oriented learning environment, where students appropriate and apply these principles in technology innovation.

At Aalborg University Denmark several attempts have been made to integrate sustainability into ICT education within the framework of a problem based learning framework. Problem Based Learning (PBL) is a learning approach constituted by problems in contexts as well as interdisciplinary, collaborative and participatory principles. In some of the more comprehensive models, problems are characterized as ill-structured, as they are drawn on real life situations, and the problem solving process and final solution are thereby unknown to the students (Kolmos et al., 2009).

In this paper we address the following question:

*How can students integrate sustainability into ICT projects by use of PBL method*

On the theoretical level we introduce two different models for problem analysis in order for students to move from the very complex conceptual field of sustainability to a problem formulation, which is appropriated to the time and discipline of study.

On the empirical level we draw from experiments in autumn 2009 and spring 2013 at Aalborg University, Denmark, within the field of media technology. Observations at status seminars, text analysis of students' work, students' responses from on-going semester evaluation meetings, as well as reflections from staff have been relied on in order to analyse the practical implications of the following problem analysis strategies to address the challenge of SD.

## **2. Strategies for problem analysis - Top- down and bottom-up**

Aalborg University has based all educational programmes on a problem based and project oriented learning model. At the faculty of engineering and science each semester consist of three course modules of 5 ECTS and one project module of 1 ECTS. The PBL model emphasises real life problems as points of departure for active self-directed and exemplary learning (see Graaff and Kolmos, 2007). The model at the faculty of engineering and science have formal courses half of the time, playing a subsidiary or supportive role, whereas the other half of the time is allocated to semester-long projects in groups. Each project module has a problem theme, also called semester theme, which is a general and complex conceptual field from where students have to relate and formulate a more concrete and narrow problem to solve. In the second semester of the media technology bachelor programme the themes have been related with sustainability.

During the first year students learn how to manage a problem-based project and to contextualise technical problems by embedding them into a broader societal context. First they learn to understand the different origins of a problem and the different strategies for problem analysis that this implies. We argue that there are at least two very common origins of technological innovation.

First of all, a problem can arise from the fact that some people consider a certain situation as unsatisfactory. Here the challenge for students is to document and discuss the nature of the problem and assess the societal constraints on the practical, institutional and discursive level. This provides different solution scenarios, which can be assessed, e.g. by constructive technological assessment. Based on this assessment students can argue for a given solution scenario and a problem formulation is stated. In a course module on first semester staff present this to the students as a bottom-up problem analysis approach to narrow down the problem to be addressed.

Secondly, a problem can be view by a lack of attention/action to a yet explored potential. In this case the students enter into a creative process to picture different visions/solutions by combining different technologies and assess their potential of providing something new to the existing yet somehow comparable technologies. If a potential is argued (that we can do it), it becomes a solution in search of problems or at some kind of added value. As an example, a lot of features going into smartphones of today can hardly be said to have their origin in “an unsatisfactory situation” – it is, at least before it enters the field of habitus, an added value to the experience of life. This is presented to the students as a top-down problem analysis providing another way to narrow down the theme to a specific problem to be addressed. Also in this case, as in any case of technological innovation, the drivers, barriers and impacts of appropriating the technology into the socio-cultural context should be considered.

These two different approaches to narrow down the theme to a problem statement are illustrated in figure 1. In the following, practices aligned with these two models for problem analysis are presented drawing on experiences from integrating sustainability in Media technology education at Aalborg University.

## **3. Mediatechnologists for sustainability**

Mediatechnology is an interdisciplinary field integrating design, communication and computer science, e.g. addressing Human Computer Interaction. The program was initiated in 2006 at Aalborg University. Media technologists are concerned with how a particular message can be mediated and adapted to the target group by use of electronic means. Technically, they work with animations, computer games, applications, sound and films, graphics and interactive environments.

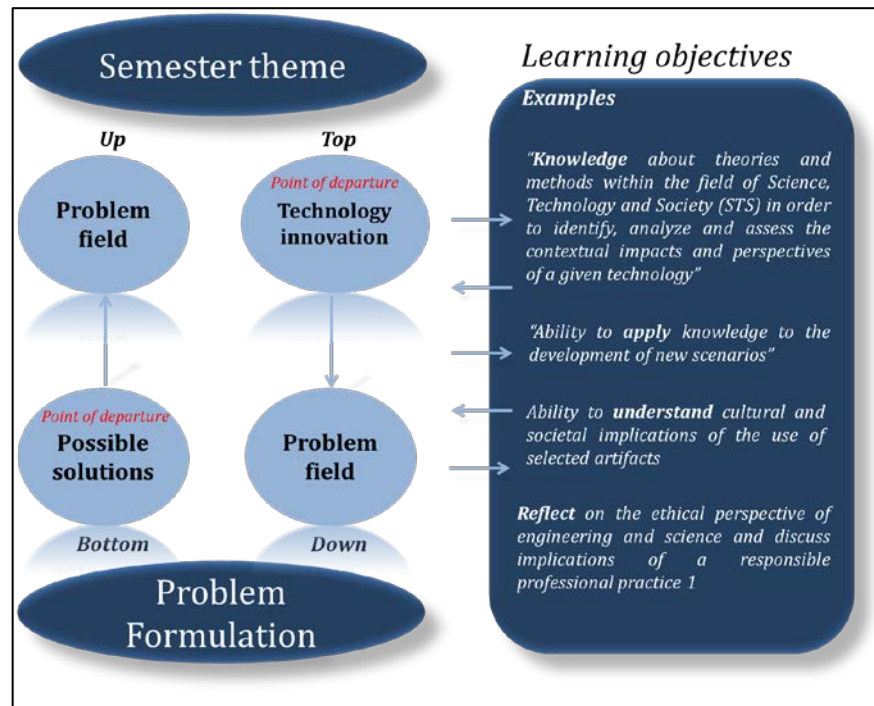


Figure 1: Different approaches to problem analysis – top-down and bottom-up

(learning objectives taken from bachelor programme of Media technology written curriculum).

In 2007, 2009 and 2013, the first semester coordinators of the Media technology program initiated different efforts in the field of education for sustainability (ESD). In 2007, students were introduced to SD in the course technology and society. This motivated a few groups to address sustainability in their projects, as an example one group made an edutainment game to educate school children about sustainability. In 2009 the ESD efforts were formalized by introducing climate change as the semester theme, making it compulsory for students to address problems related to climate change in their projects. This initiative was aligned with COP 15 in Copenhagen, whereas students were also motivated by the public and political debate on the reasons, the problems as well as possible solutions to the climate change challenge. In 2013, the students were introduced to sustainability as a part of new course on Problem Based Learning (PBL) & Science, Technology and Society (STS), which covered all the material of the previous course in Media technology, technology and society. Again the semester theme was used to initiate sustainability projects, this time by introducing sustainable lifestyles as the theme to be addressed by a human computer interaction (HCI) approach.

In 2009, the semester was kick-started in the first week by dividing students administratively into groups of about seven, and demanding these groups to make at least two project proposals each including a title, problem motivation, problem statement, visions of products as well as methodological considerations to the problem analysis, design and implementation process. At a seminar, students presented these project proposals and formed groups in a self-directed process (i.e. according to their interests). In 2009, students felt that the time they spent in the administratively divided groups was not really paying off in the “real” project group formed afterwards; therefore this process was reduced to a one-day speed-dating event in 2013. .

In 2013, students worked within a thematic frame of sustainable lifestyles. In example box 1, in page 6, please find the written outline of the semester theme as background information and for possible inspiration.

This semester theme was introduced at the speed dating session and after that the facilitators divided students into groups for a couple of hours to develop ideas for projects and make posters to be presented by elevator pitches. After the pitches, posters within the same area was clustered, and students “voted” on the posters by distributing three votes on the ideas they found most interesting for further work. After that the students formed groups, by taking into consideration the subjects of interest as well as social relations. After group formation they were assigned 2 supervisors – one with special attention to the design and implementation of technology, and one with specific attention to broader societal context.

Two status seminars were provided along the way; one challenging the students to come up with at least three ideas on how to address sustainability by use of ICT; and one reporting on the problem analysis and presenting the problem formulation. At the second seminar an Engineering Education researcher (not a part of the teaching staff) was present to make observation from the “outside”. At both seminars all groups were present to learn and provide feedback from their peers, and all students were asked to bring their computers in order to type in on-going feedback. In this way many students could have “a voice” although time for oral comments was limited. At semester group meetings, students responded positively to these sessions, although some argued for more time than 5-10 minutes to elaborate on their project – whereas others appreciated the challenge of extracting the most essential points to present and provide overview.

From the first seminar the following conclusions were that the students addressed very divers aspects of sustainability. Three groups stressed environmental aspects: Visualizing energy consumption (2 gr) and educating children for environmental protection (1 gr), and getting people to use CO2 neutral means of transportation. Four groups stressed social aspects: Children and overweight (1 gr), mental health to prevent depression (2 gr) and sustaining cultures (1 gr). Finally, four groups stressed resource/natural aspects: Getting people to use the trash in public places (2 gr), to save water in the shower (1 gr), and to increase the market shares of organic food (1 gr).

From the second status seminar it became clear that both top-down and bottom-up approaches to problem analysis are present as a result of their decisions on process analysis and problem formulation. This provided the students not only a strong motivation to work with technological solutions but also to target and argue for their potential towards sustainability. In addition, the relation they established between technological innovation and sustainability allows a gradually construction of sustainability as a concept. If students do not have the opportunity to do that, the facilitators’ experience point that they will start with a rather symbolic problem analysis – just for the sake of it, and almost by magic ending up with their vision from day one.

The typical top-down approach could be characterized by “Apps in search of sustainability problems”, where they have their point of departure of an unexplored potential and from a strong believe in apps as a persuasive technology towards sustainability. The vision of an app went far: apps to help children gain and develop a healthy lifestyle, apps to direct you to organic food in the shops or what about apps to monitor your ecological footprint. Others took their point of departure in intelligent technology for housing, e.g. intelligent lightning or the intelligent shower who will turn of the water when you take soap in your hair. And yet others were inspired by “the fun theory” (see for example <http://www.thefuntheory.com/worlds-deepest-bin>) making technologies that are more fun to use and thereby provide incentives for, e.g. collecting and sorting garbage for recycling purposes.

**Example BOX 1: Semester theme on sustainable lifestyle**

Unless we change our current lifestyle patterns it will not be possible to keep the high levels of quality of life currently enjoyed. According to Mont (2007) sustainable lifestyles are patterns of action and consumption, used by people to affiliate and differentiate themselves from others, which: meet basic needs, provide a better quality of life, minimise the use of natural resources and emissions of waste and pollutants over the lifecycle, and do not jeopardise the needs of future generations.

As sustainable development is seen as one of the “grand challenges” of our time, several top-down attempts have been made from governmental institutions to foster more sustainable lifestyles, especially in the industrialized parts of the world where the ecological footprint cannot easily be overlooked. One initiative is the SPREAD project representing a European social platform for Sustainable Lifestyles 2050. In this project working groups including researchers, business partners and non-governmental organisations are working together to provide sustainable transport, housing, consumption patterns and infrastructures.

But it is not enough to create policies, strategies and plans for more sustainable lifestyles; citizens need to have access, will and competences to act accordingly to bring about the required changes in a bottom-up fashion. As stressed by Van der Ryn & Cowan (1996), the environmental crisis is in many ways a design crisis. In the IT sector, recent pushes for sustainability have focused on designing computers, applications and services to make individual attitudes and behaviours more sustainable. This work has been drawing on theories and concepts from psychology and behavioural economics (see e.g. DiSalvo et al. 2010) but also considered people's practices, e.g. around cooking, cleaning, and moving about, which are often determined by cultural norms and conventions rather than individual decisions. This has led to the creation of a new field called persuasive technology (see Fogg 2003).

In the field of media technology, the challenge is to:

- understand people's decision making that impact sustainability in their actual context,
- design solutions to increase motivation, awareness, skills and competences for citizens and communities to live sustainable lifestyles, and
- critically assess the impact of these hopefully more sustainable trajectories.

For designing persuasive technology you should consider some of the strengths of technology when used in persuasion as opposed to human actors such as:

1. persistence,
2. possible anonymity,
3. storage, access and manipulation of large amounts of historical and forecast data,
4. usage of many modalities,
5. scalability and network effects (it works well for many people, potentially even better the more people use it), and
6. ubiquity.

Projects could point to websites, applications, mobile phone apps or video games, which encourage/motivate people to change their patterns in a more sustainable direction. Different target groups could be in focus as well as different motivations and behavioural impacts. Different motivations could for example be more sustainable transportation, reduction in energy consumption or consuming less through abstinence, recycling, and deferring or shifting consumption times.

The goal could be:

- A web-side informing about sustainable tourism
- An application monitoring energy use in a household
- A mobile app to guide costumers on-spot for sustainable shopping
- An edutainment game educating school children for sustainability.

...or whatever you can imagine to create media technology for sustainability!

The challenge for these groups was, however, to be able to reflect critically on the potentials embedded in the vision; and the presentations tended to lead toward actually defending their ideas without much scientific ground. For example, one group made up personas. Descriptions of fictitious personas, or in other words narratives of the appearance of a fictive character, provides a method for representing generalisations of target group research in order to direct the designing process (see for example Cooper, 1998). However, after presenting some rather doubtful fictitious personas at the status seminar, the group was questioned regarding the methodology for target group research – but surprisingly they represented data, which were non-existing. They simply made them up.

Fewer, but yet some, groups started bottom-up by gathering insights on the problem in its context, e.g. focusing on why people tend to take the car on short distances, understanding the need for sustaining ones culture as a foreigner, or different ways to prevent depression. These groups provided very reflective insights in the problem field of investigation and had throughout argumentations of *what* constitutes the problem, *why* there is a need to address this problem, and *what* a possible solution could be. However, this bottom-up takes time, and the presentations revealed that the students kind of rushed into appropriating technology to the situation – and did not really have the time needed to figure out *how* the solution could be design and implemented. What started as rather ambitious ended up in rather naive ideas considering the *how*, e.g. preventing depression by playing a game where you have to guess a number or providing Italian kids with language tools in order to sustain their culture.

However, whether or not the students started from a vision/solution or problems from real life situations – they tended to have a hard time working systematically with their problem analysis. It seems like there were too many degrees of freedom. The complex concept of sustainability were open for interpretation, the complex problem field provided hundreds of alternative problems as well as visions and furthermore the problem analysis process also were addressed as it was rather open for interpretation and the two overall approaches introduced in the course was remarkable vague in students conscience. The lesson learned is that the degrees of freedom have to be limited in order to enable students' to reach all learning objectives (in the design, implementation and test phase).

This also questions the choice of theme for the semester. The experiences from 2009 where those students were addressing climate change “at a distance”; the long term perspectives and the political debate at that moment made them see climate change as a rather abstract concept having not much to do with their everyday life. This made it hard for them to actually internalise the knowledge they gained about sustainability. However, although sustainable lifestyles referred to their everyday life, not many actually went “into the lab” using their own everyday practise to reflect possible changes and reflect on this in situ. This also means that the problem is narrowed down to a very concrete and contextual problem related to sustainability and in this way students can gradually move to a more abstract and multi systemic approaches on sustainability.

## 5. Conclusion

In this paper we present different approaches to integrate sustainability into Information and Communication Technology (ITC) projects by use of problem based learning methodology at Aalborg University.

The introduction of an open-ended thematic frame encouraged students to broaden their perspective on sustainability stressing economic, environmental as well as social concerns. Students approached this broad theme with very limited subject knowledge; making it complex for them to address sustainability. Whereas some seem to fall back on a common sense understanding of sustainability, others choose rather untraditional and rather interesting approaches. Whereas the open-ended start



seemed to be enough to kick-start creative thinking, on-going ad-hoc seminars could have been supportive in the problem analysis phase, as the information on sustainability is so extensive that students can find it hard to select among the many Google hits. This could be one way to limit the degrees of freedom in order to make students capable of actually getting the time design, implement and test a solution.

Another way to limit the degrees of freedom could be to guide students more in terms of how to structure a problem based project. The methodological awareness was rather low and it becomes clear that the students did not have a clear understanding of the possible methodologies. They have had a course on the previous semester providing students with the methodologies to make top-down/bottom-up problem analysis – but students had a hard time to transfer this knowledge to their projects; whereas a closer integration and alignment of courses about and projects for sustainability are needed.

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